MANPRINT Quarterly

PEOPLE TECHNOLOGY ORGANIZATION

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The Director's Corner

The article by LTC David Dorman on MANPRINTing Javelin describes a commendable success. A hugely effective anti-armor weapon system was designed and developed for the Infantry. By skillfully engineering a modular design this hard hitting, highly accurate weapon was made portable for light infantry. By thinking ahead to the tactical environments in which this modular system will be deployed, with the load distributed among the members of a rifle squad, the TRADOC Systems Manager (TSM) is focusing the Infantry School on the required doctrine and training for tactical operations—e.g., rapid action responses to enemy contact. I applaud the Javelin Program Manager, TSM, and the Infantry School for their work. We are also pleased to present in this issue an article on the Apache MANPRINT program success and methodology by Mr. Don Crabtree and a very timely article on heat stress in combat vehicles by Mr. Ajoy Muralidhar.

Jack H. Hiller
Director for MANPRINT

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Continuous MANPRINT Development in the Javelin Antitank Missile

by LTC David Dorman
Assistant TRADOC Systems Manager
Antitank Missiles

We have always heard that MANPRINT has its biggest payoff in the early stages of a program. The focus of this article is the continuing role of MANPRINT after that initial emphasis—after the early stages of development are complete. MANPRINT was a key element during the Proof

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MANPRINT Directory

Requests for the 1995 MANPRINT Directory should be faxed or mailed to:

Office of the Deputy Chief of Staff for Personnel
HQDA (DAPE-MR)
300 Army Pentagon
Washington, DC 20310-0300
FAX: DSN 227-1283
COM (703) 697-1283

NOTE: The last published edition of the "MANPRINT Quarterly" was Summer 1995. Funding constraints prevented publication of a Fall 1995 edition.

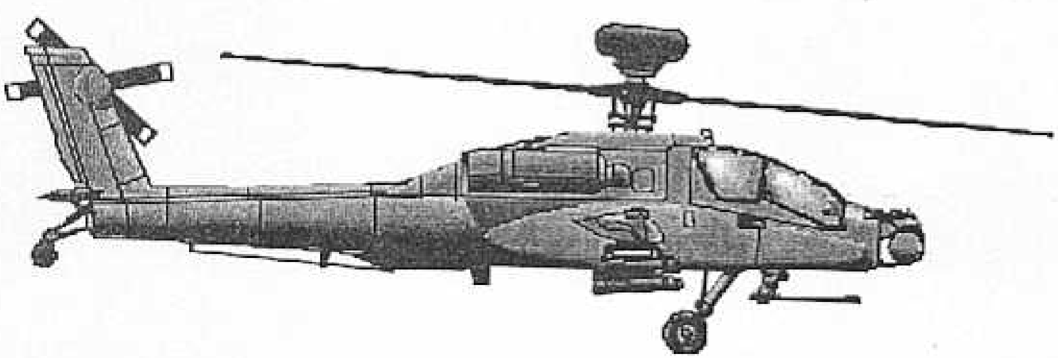
MANPRINT

Spending Your Nickels Wisely

by Don Crabtree
MANPRINT Manager, AH-64 Apache Attack Helicopter Program

Would you spend a nickel today to save a dollar tomorrow? Do you recognize the value added in spending a nickel for design fixes up front versus spending dollars for extra manpower costs in the future? The Apache Attack Helicopter Project Manager answered yes to these important questions and instituted a MANPRINT program to influence design of the modernized Apache. This article explains the Apache MANPRINT program.

The Apache Attack Helicopter MANPRINT program



as been very successful in ensuring each of the seven IANPRINT domains are considered throughout the degn process and system life cycle. The overall objective f the program is to minimize operator workload, maxiize maintainer efficiency and eliminate personnel hazrds and equipment damage. It has emphasized the need r effective man-machine interface to achieve optimal stem performance. Since its inception in 1989, over 200 concerns (referred to as observations) have been adessed and documented. About half of these concerns ere accepted as valid MANPRINT issues and were orked or are being worked until final resolution. The ANPRINT program has had a definite impact on design anges, technical documentation, training courseware, oduct improvement, and elimination of hazards. The llar savings realized by applying MANPRINT principles roughout a weapon systems life cycle is difficult to quany. However, if risk of death, injury, and equipment deuction or damage can be minimized, and if efficient personnel utilization can be maximized, the program is successful. Since these MANPRINT accomplishments will have a major impact on effective operator/maintainer performance and the reduction of safety risks, the MANPRINT program was cost-effective.

MANPRINT Program Management

The major ingredients of the program's success have been the program's efficient management, the wide range of both industry and government involvement, and the support and hard work of key personnel. Some of the ideas specifically instituted and the tools employed in the program are described below.

All Apache series aircraft have common hardware and were consolidated into one MANPRINT program. This provided opportunities to review lessons learned and eliminated duplication of effort. This consolidation has demonstrated continuity, consistency, and effective utilization of resources.

A MANPRINT Joint Working Group (MJWG) charter was developed to supplement the System MANPRINT Management Plan. The charter provides specific direction in conducting MJWG meetings and establishes frequency, chairmanship, responsibilities, and membership. A process flow diagram for issues and concerns is included. Each concern (observation) is thoroughly evaluated prior to being accepted as a MANPRINT issue.

An Executive Council comprised of representatives of the Project Manager's Office; U.S. Army Aviation Center, Director of Combat Developments; TRADOC System Manager; and the U.S. Army Research Laboratory, Human Research and Engineering Directorate was established. This council meets approximately one month prior to the MJWG meeting to review issues and concerns and prepare recommendations to the MJWG on appropriate courses of action. In order to resolve issues as quickly as possible and to keep members informed on the latest actions and status, the Executive Council and MJWG meet twice a year.

MJWG meetings always have a broad base of representation present. Membership includes the Executive Council, contractor MANPRINT representatives, and all agencies responsible for the individual MANPRINT domain assessments. In addition, numerous other commands/agencies and project/product managers are invited to attend. This ensures the most knowledgeable decision makers are in attendance.

Read-ahead packages which depict the issues to be discussed, the latest status, and any Executive Council recommendations are prepared and distributed to all prospective MJWG attendees. Each recipient is tasked to thoroughly review the package and attend the meeting prepared to discuss the issues. This adds tremendously to the efficiency and accomplishments of meetings.

When an issue has a recommended course of action established, but is not yet in effect (awaiting funds, analyses, test or documentation, engineering inputs, etc.), it is placed into a deferred category. These issues are reviewed by the MJWG only when these pending actions have been completed. Prior to closing an issue, all corrective actions are certified as completed and the issue is verified as being satisfactorily closed.

All issues not in a deferred category are referred to action agencies at the MJWG meeting. Suspense dates are established and follow-up actions are taken to provide recommendations and solutions. These action items are documented in the meeting minutes and discussed at the next meeting.

Minutes are prepared for both the Executive Council and MJWG meetings and distributed as quickly as possible (normally within one week). Issues requiring action are listed as well as the agency responsible for performing that action.

A dedicated MANPRINT database and tracking record was established to monitor and store all concerns and issues. This database was designed to easily identify the originator, address the concern, identify the domains affected, prioritize the issue, and document the recommendations, status, and action agencies assigned. A number of sort and search options were built in to provide summaries and fast retrieval of historical data. To ensure accuracy and completeness, the Project Manager assigned a dedicated MANPRINT manager with overall responsibilities for the program.

The MANPRINT program is thoroughly integrated throughout the Apache Attack Helicopter program. Agencies and working groups involved with the Apache are diverse, widespread, and often very specialized. As a result, communication between these groups is difficult without central integration. In order to eliminate duplications of effort and ensure solutions developed by a particular group do not adversely impact other areas, issues are transferred to these groups. The MJWG monitors these ongoing actions, and the MANPRINT database documents actions and recommendations set forth. Examples of these diverse groups include the System Safety Working Group (SSWG), Apache Readiness Improvement Program (ARIP), and the Integrated Logistics Support Management Team (ILSMT). There have been several instances where this approach has not only prevented conflicts from arising, but has created a synergistic effect on other group activities, thus reducing resource expenditures and enhancing the solution to an issue/observation.

All prime contractors consider MANPRINT in their design decisions. This requirement is included in all statements of work and contracts. MANPRINT status reports and plans are also received as contract deliverables.

Program/project/product manager commitment to the MANPRINT process is a must. Apache managers are supportive and actively involved in the MANPRINT program. Their involvement has added substance and creditability to the program and has led to what is reportedly one of the premier MANPRINT programs in the Army.

Major Accomplishments

One of the more noteworthy MANPRINT accomplishments has been the identification and resolution of maintainer accessibility and attaching hardware problems. A top priority in the conversion of Apache AH-64A series to the AH-64D configuration was ensuring there would be no increase in manpower or personnel requirements. During the contractor and Government Logistic Demonstrations, 275 maintenance concerns were documented by

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Letter to the Editor

The following letter was written in response to the article, "Why MANPRINT Makes Sense for Streamlined Acquisition," published in the Summer 1995 issue.

I enjoyed reading your article but was struck by a singular observation. That observation is not that MANPRINT is not a good thing, it is, but by the fact if what you say about the Stinger, the MLRS, Black Hawk and FDIS is correct, then the Statement of Work for these contracts was IMPROPERLY STATED.

That is to say the Systems Engineering did not properly define the requirements. Had these requirements been properly stated at the onset, then almost all of these problems depicted in your article would have been eliminated in the Full Scale Design process.

While Human Factors Engineering is the new frontier for achieving increased performance and suitability, some very basic design engineering is also required. That seems to be what you are saying, not that MANPRINT was neglected but that the requirements were not properly stated and that the contractor was allowed to field a system without really providing what was wanted and needed.

The neglect of the System Safety Working Group, a basic MIL-STD-882 requirement, is a Program Management SNAFU. Neglecting these kinds of issues leads to the inevitable "Rubber on the Ramp" thing that the USAF went through for years. Life Cycle Cost requirements drove that philosophy out of USAF procurement process and ought to have done so in the Army too. MIL-STD-882 produced markedly safer and more reliable aircraft, and summarily reduced the mishap rate for logistics accidents in the USAF.

The "incompatibility" of the SINCGARS is a classic example of not properly stating the requirements. The "Inattention to the MOS..." is a classic neglect of good old standardized Logistics Engineering.

In short, your article continually puts forth the theme of not the lack of MANPRINT or requirement for doing it, but rather the failure to develop and state the contract requirements correctly.

I agree with the recent Secretary of Defense's "policy of streamlining." There are many good things that can and ought to be done to improve the procurement process, but many of the "Lessons Learned" are imbedded in the MIL-STDs. These were the tools that helped produce the good equipment. Even today we are feeling the pressure to eliminate System Safety as a "Not Value Added" item to contracts. We, the U.S. taxpayers, will be paying for shoddy unsafe equipment in the not too distant future.

I hope that you are successful with MANPRINT, but I fear you will also face the "No Value Added" theme in the future. Program Managers mean well and want to get the most for their dollar, more bang for the buck, but are often short sighted, seeking only the next promotion cycle. The MIL-STDS were the tools used to force the Program Managers to get it right the first time.

William C. Morrison, CSP
Colonel, USAF (RET)

MANPRINT Training Schedule

MANPRINT Action Officer Courses

Class	Date	Location
96-703	22-31 Jan 96	Redstone Arsenal, AL
96-704	5-14 Mar 96	Fort Huachuca, AZ
96-001	15-25 Apr 96	USALMC, Fort Lee, VA
96-705	14-23 May 96	Fort Hood, TX
96-706	30 Jul - 8 Aug 96	Fort Monmouth, NJ
96-002	9-19 Sep 96	USALMC, Fort Lee, VA

MANPRINT Workshops

Class	Date	Location
96-705	6-8 Feb 96	Fort Hood, TX
96-708	30 Apr - 2 May 96	TACOM, Warren, MI
96-709	7-9 May 96	Redstone Arsenal, AL
96-710	4-6 Jun 96	Fort Bliss, TX
96-713	20-22 Aug 96	Redstone Arsenal, AL

MAISRC

Class	Date	Location
96-707	19-22 Mar 96	Fort Belvoir, VA
96-714	10-12 Sep 96	Fort Belvoir, VA
96-715	24-27 Sep 96	Fort Huachuca, AZ

MANPRINT Training POC: Mr. Jan Dykhuis, (703) 325-2098 or DSN 221-2098

Thermal Stress as a Performance Restricting Factor in Ground Combat Vehicles

Ajoy Muralidhar, MANPRINT Engineer
United Defense L. P., Ground Systems Division - York, PA 17405-1512

Nothing seems to bring home the limitations of "carefully designed and tested" military equipment like operations on actual terrain in remote regions of the world. It happened to the United States in southeast Asia and in the Gulf War, the British experienced it in the Falklands, the erstwhile Soviet Union in Afghanistan and more recently, the Russians in Chechniya...as experience with exposure to such degraded environments increases, armies try to ensure that the enhanced requirements are included in future acquisitions and through system upgrades. Although this may take care of hardware shortcomings (until the next major operation throws up new ones), the troops who are to conduct operations in these adverse regions are subject to the same harsh conditions, and there is little that can be done by way of "upgrading" performances, especially if the mobilization is at short notice.

The most immediately felt impact, of course, is that of the dramatic change in the climatic conditions experienced. Operations in the desert in particular can impose a great physiological strain on combatants, due to the fact that usually very little time is available for acclimatization. Although the troops may not be immediately forced into combat, there still remains the need for extensive preparations prior to engaging the enemy—deployment, maintenance, exercises, etc., all of which call for high activity levels, leading to greater metabolic activity and heat production. Further, the operational scenario imposed requirements of clothing, protective equipment, communication devices and field equipment that the modern soldier is burdened with further increases the thermal loads experienced due to the limited amount of exposed body surface available for evaporative cooling.

The thermal environment experienced by a soldier is one of the most significant factors which affects performance as it directly determines the comfort level and influences productivity. Although performance improves with acclimatization, individual variances in the adaptation period are very great, and physiological response of a body of troops to the same sustained climatological conditions may vary greatly depending on the physical condition of the individual, the training, and on different combinations of clothing and activity. As human response to the thermal environment is very subjective, it becomes very difficult to define thermal comfort—it is the individuals' acceptance of perceived ambient conditions as tolerable, or the zone where the body can establish equilibrium with the environment without causing psychological or physical distress. Because of the wide variances experienced, this so-called "comfort zone" depends not only upon the ambient temperature, but also on other factors such as the relative humidity, the work load, the clothing, air movement and protective equipment.

Although comfort plays a great part in the continued motivation of an individual to perform, it is the physiological parameters such as skin temperature, core temperature etc., that serve to indicate safe levels of human thermal response. Technically, an ideal state of human thermal response is when the body heat storage is reduced to zero, and the core temperature is maintained at 37°C (98.6°F) ± 1°C (1.8°F). The maintenance of this core temperature and dissipation of stored body heat requires a constant heat exchange between the body and the environment, and is regulated by the laws of thermodynamics. The mechanisms of heat dissipation may take several forms, such as evaporative cooling, convection, conduction, radiation, and heat loss through other bodily functions like defecation and urination.

The thermal environments encountered by troops that are required to operate ground combat vehicles pose some challenges to designing heat dissipation mechanisms to aid the body's thermo-regulatory processes. By their definition, a ground vehicle used in combat is most likely heavily armored, and is designed to protect its crew and equipment from enemy threats, including munitions, shock, blast overpressure and nuclear, biological and chemical threats. These requirements place severe constraints on the designer/MANPRINT practitioner trying to incorporate human engineering, health hazard and safety requirements on these vehicles.

The survivability requirements of the combat vehicle force the crew to work in a closed, sealed environment, dependent upon forced air circulation through the vehicles' life support systems. In addition to the heat generated by the metabolic activity of the crew, there is an enormous amount of waste heat generated by the systems' on-board electrical and electronic systems, heat radiated from the powerplant, weapon system, thermal loading of the vehicle exterior through

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Continuous MANPRINT Development in the Javelin Antitank Missile

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of Principal (POP) Test Program and was emphasized in both the POP and Full Scale Development (FSD) Requests for Proposals.

During POP, the early Advanced Anti-Armor Weapon System - Medium (AAWS-M) MANPRINT effort was extremely intense and drove the design of the system we now know as Javelin. Lessons learned in the Dragon program were documented early by the MANPRINT Joint Working Group, and a comprehensive System MANPRINT Management Plan (SMMP) was developed and closely followed. Early mock-ups were developed, and handling characteristics, center of gravity, and controls and displays were assessed by the MANPRINT Team. The team consisted of personnel from the Contractor, Project Office, and the User, aided by the Human Research and Engineering Directorate field offices at Fort Benning and Redstone Arsenal. Additionally, three different training programs were evaluated, and training device effectiveness was analyzed during a Training Force Development Test and Experiment (FDT&E). A comprehensive training program of instruction was developed for the Initial Operational Test and Evaluation based on the FDT&E results.

Some of the successful key initiatives in the FSD phase of the program included early and continued Soldier/Marine-in-the-loop testing; delivery of mock-ups and video tapes with the FSD proposal; a one-time MANPRINT Data Item Description prepared to facilitate development of the MANPRINT program and test reports; high visibility of MANPRINT during FSD Post Award briefings; a requirement for the contractor to address each concern listed in the SMMP; and continued MANPRINT testing.

The early MANPRINT work resulted in a system design which is vastly improved over the design of its predecessor system in five of the seven MANPRINT domains, and the other two domains, Manpower and Personnel, were not adversely impacted. As one result, soldier survivability is enhanced. Instead of the Dragon's wire-guided missile, which required the gunner to be exposed during tracking, the Javelin is a fire-and-forget system. All gunner tasks are accomplished prior to missile launch. Training benefit is gained because the tracking task (which has great skill decay) is no longer needed during sustainment training.

Furthermore, a suite of training devices was developed which includes the Basic Skills Trainer (BST), Field Tactical Trainer (FTT) and Missile Simulation Round (MSR) to support the critical training tasks. The BST is a computer based classroom trainer. The FTT accomplishes two different missions. It is both a range trainer, with an attached monitor for instructor feedback, and a force-on-force MILES trainer. The MSR provides the gunner a weighted field trainer to preclude unnecessary wear and tear when training does not require the MILES FTT feedback.

Human Factors Engineering was optimized. The Javelin display provides intuitive feedback to the gunner so that he does not have to remember a lot of sequential tasks which would make him error prone. The Javelin is a soft launch missile and does not create the blast overpressure problems of its predecessor, thus minimizing Safety and Health Hazard risks.

The Javelin MANPRINT Team did not stop work after its early success in influencing design. Further important MANPRINT work is being done during the Production and Deployment Phase of development. Numerous examples of how the MANPRINT Team has influenced the design of Javelin and its training devices could be described. I have chosen three illustrative examples to make the point.

For most tactical systems, training devices do not receive the same emphasis as the tactical weapon system. The Javelin MANPRINT Team realized early on that live fire training with Javelin would be cost prohibitive and that the training devices needed a high degree of tactical system fidelity. The Javelin FTT and the BST demonstrated their worth during the Initial Operational Test and Evaluation, where gunners trained with these devices fired live missiles and hit 89% of their targets. This was considered a major achievement and yet deficiencies were noted. In order to field the most robust trainer possible within cost, the Infantry School Directorate of Operations and Training, in coordination with the Javelin Assistant Project Manager for Training Devices, developed a detailed issues sheet that prioritized deficiencies and identified them as either negative training, reliability or other issues early in the Production and Deployment Phase of development. The Project Manager then dedicated software and hardware engineers from his Technical Management Division to an FTT and BST Improvement Program and established a separate contractual effort to address all the prioritized issues identified. This approach focused the Texas Instruments/Lockheed Martin Javelin Joint Venture into a parallel effort of equal emphasis. Separate management reviews were conducted to track progress as testing and developments warranted. On numerous occasions the Joint Venture sought and received direct user feedback during their development efforts.

As of this writing, technical testing of the FTT and BST is being completed with very encouraging results. A Soldier/Marine "early look" of the FTT at Fort Benning will be conducted just prior to the technical qualification tests as one last opportunity for Soldier/Marine design influence before operational testing and initial fielding.

Another example of how the Project Office, Contractor, and User have jointly combined to address MANPRINT domains is found in the development of technical publications. At the very beginning of the Production and Deployment Phase of system development, a Joint Working Group meeting was held to discuss the process by which the technical publications would be developed. The plan developed was comprehensive with multiple in-process reviews. At these page-by-page reviews, User representatives from the Infantry School and the Marine Corps sat down with the Javelin Joint Venture technical writers and Project Office personnel. Discussions frequently revolved around what the Soldier/Marine needed to know versus the technical underpinnings that Engineers might have more interest in. When possible, reviews were conducted with the hardware and soldiers to eliminate doubt about how equipment worked. Additionally, the writers received first hand feedback from Soldiers and Marines during the writing stage to see if the words and artwork conveyed the message needed in a clear and concise manner. Draft submissions will receive further feedback during the Fort Benning User Evaluation and then again after the Limited User Test at Fort Hunter Liggett. Final changes will be incorporated into the Final Draft submission that will be used to field the First Unit Equipped. This process has not saved time; however, the quality of the product and needs of the Soldier clearly are going to be better met as a result of this effort.

Furthermore, the Infantry School had a need to field concurrently with the Javelin a Student Handout that discusses tactics, techniques, procedures, and battle drills for employment of the Javelin. Included in this document is guidance to leaders that addresses concern for soldiers when carrying their sustainment load and the Javelin. This Student Handout will receive feedback from the field and eventually become a published Field Manual for the employment of Javelin.

One final example of how concerns for the MANPRINT domains have influenced design is found in the full rate production Command Launch Unit (CLU). An Enhanced Producability Program was initiated to simplify manufacturing design in order to lower production costs after the initially fielded Low Rate Initial Production CLU. At the earliest opportunity, the Javelin Government/Contractor MANPRINT Team was evaluating the man-machine interface using mock-ups. After three reviews with Soldiers and Marines, several design changes were incorporated. This early Soldier/Marine influence is expected to pay the Army and Marine Corps great dividends by having a system developed and fielded that should not require future improvements.

The Government/Contractor MANPRINT Team is to be commended for its effort to keep a constant vigilance on each of the MANPRINT domains during the development and production of the tactical system and training devices. The Javelin Project's overall excellence was recently recognized by its selection for the Daedalian Weapon System Award. This award is presented annually to one recipient in the Army, Navy, or Air Force for having the most outstanding aerospace weapon system program. The final test of the Javelin MANPRINT Team efforts, of course, will be how the gunners and the equipment perform in combat. Feedback from Soldiers and Marines during development leads us to predict at this point that the Army and Marine Corps are going to have a winner.

Thermal Stress as a Performance Restricting Factor in Ground Combat Vehicles

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solar radiation, etc. The survivability requirement of a non-reflective outer coating on combat vehicles increases the absorption and retention of thermal energy. The laws of thermodynamics force the equalization of thermal gradients throughout the vehicle, whatever the source, with the whole vehicle being subject to "heat soaking." The massive hull and armor serves as a heat sink, storing excess thermal energy, and radiating it back into the atmosphere, when ambient temperature gradients are favorable.

When operating in daytime desert conditions, where continuous solar loading is experienced for 8-10 hours, the vehicle temperature continues to increase, unless it is moving, or there is some air movement. The protective NBC shields and Spall liners further exacerbate the problem by effectively insulating the crew compartment from the rest of the vehicle by forming a barrier and interrupting the thermal flow. This means that the crew compartment becomes, in effect, a "hot air pocket." Local gradients within this enclosed space quickly attain equilibrium, leading to thermal saturation.

Crew members working in "buttoned-up" conditions are thus subjected to high levels of thermal stress, unless the ventilation system provided is adequately designed to effectively transfer heat and keep the compartment temperature at comfortable levels. Even then, there are other problems that are encountered in providing adequate cooling to the crew members—the primary consideration is the apparel of the crew. Due to requirements of communication, which are often coupled with that of hearing protection, GCV crews have to usually wear their helmets, the prescribed battle dress uniforms for the particular region, with the associated combat footwear. In humans, the region of the head and upper body and extremities are the zones which are richly supplied with blood vessels, and through peripheral circulation, serve as the body's "heat exchangers" with the atmosphere. Combat required items of apparel interfere with the body's natural thermoregulatory processes, subjecting individual crew members to microclimates within their clothing and equipment, leading to increased heat loads and risk of heat stroke.

The risk of heat stress and heat stroke increase considerably if the crew also has to perform heavy physical work, such as lifting, loading, recovery operations and other activities. When the temperature gradients within the crew compartments reach equilibrium conditions due to saturation and air circulation, all the objects within the crew compartment (except for the components actually generating heat) are at approximately the same surface temperature, and no more heat can be expelled by convection, conduction, or by radiation. At this point, the only way the body can lose heat is by sweating. When the skin temperature reaches 34°C, peripheral circulation increases, and copious sweating occurs. Sweating cools the body by means of evaporation, and in micro-climates where the evaporative process is hampered, core temperature increases.

The effects of increased core temperatures are nausea, giddiness, loss of muscular performance, reduction of efficiency, cramps from salt imbalance and unconsciousness, leading to death. The exact physiological response to increased core temperatures varies greatly with individuals, but loss of performance can generally be taken as a given. Reduced efficiency will adversely affect mission performance and survivability.

As the limitations of geography, survivability and operational conditions on thermal conditions inside Combat Vehicles cannot be corrected by design, measures must be taken to reduce the exposure time of combat personnel to thermal stress. This can be done by reducing the length of time they are actually at their stations. One possible solution is to assign multiple crews to combat vehicles when operating in desert environments, so that crews can be rotated frequently, and thus are at peak levels of efficiency. This would raise problems of manpower availability and transportation, to say nothing of transition requirements between crews. However, this may be a viable solution in the early phases of the mobilization, until the crews have had sufficient exposure to the changed climatic conditions so as to become acclimatized. The acclimatization process takes several weeks, and consists of the body's physiological processes adapting to the changed conditions by adjusting salt loss, losing body fat, stepping up perspiration production, increased circulatory response and increased fluid intake.

To counter the risk of thermal stress to the combat crewperson, it is necessary to monitor personnel continuously during operations in these conditions. In order to do this, it may be necessary to set up a system to alert the crew when heat stroke inducing conditions may be present. This may take the form of a monitoring system that measures outside and internal temperatures, air flow rates, heat transfer rates, relative humidity, and temperature gradients within the crew compartment. The alert could be a visual or audible signal, and the monitoring system is integrated to the CV's microclimate control system. The alert serves to warn the crew that precautions must be taken to reduce the heat stress.

Some precautions that may be followed by combat crews to minimize the effects of heat stress are as follows:

- drink small quantities of fluid frequently to prevent dehydration. A sufficient quantity of lukewarm or warm water, sweetened coffee or tea should be made available to the crew members.
- if possible, take adequate rest pauses during periods of heavy work.
- avoid clothing that is not absorbent or easily permeable. This will trap heat close to the body.

Air circulation inside the crew compartment should be augmented by the use of small electric fans, strategically located at each crew position to aid in sweat evaporation. Due to the comparatively small area of the crew compartment, evaporation of sweat quickly raises the moisture content of the cabin air to the extent that further evaporation is hampered. The air filtration system must be provided with a drying agent like silica gel to absorb excess moisture from the air.

Most issues dealing with thermal stresses in the crew compartment are considered resolved when a climate control system is incorporated into the design of the combat vehicle. However, this is not always so. The climate control system should be capable of providing a comfortable working temperature of 24°-28°C under all ambient temperature conditions. Usually it is seen that under high ambient temperature conditions, the climate control systems are overloaded and do not provide adequate cooling.

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The MANPRINT practitioner has to pay special attention to these problems to ensure that issues such as the effects of rapid mobilization, lack of acclimatization, inadequate cooling and ventilation, and apparel induced microclimates are addressed during the design of the crew compartment, and in specifying personnel, training and equipment requirements.

Spending Your Nickels Wisely

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MANPRINT representatives observing the unique AH-64D maintenance tasks. These were combined with 64 previously identified maintenance issues of similar concerns and consolidated into manageable categories. A special working group comprised of the PM MANPRINT Manager; prime and sub contractor representatives; and the Army Research Laboratory, Human Research and Engineering Directorate began work immediately to resolve these issues prior to production design freeze. As a result, design engineers gave particular attention to component location, accessibility, attaching hardware and improved methods. To date, the review of new engineering drawings and actual hands on verification determined that 191 concerns have been resolved. Seventy-one are near resolution, pending government verification. Work continues on the remaining issues with satisfactory resolution expected prior to production.

Since its inception, the Apache MANPRINT program has identified, worked, and closed hundreds of issues. The dollar savings realized by applying MANPRINT principles throughout a weapon systems life cycle is difficult to quantify. When fielded, the resultant redesigns to the Apache are expected to reduce manpower and personnel requirements, improve overall readiness, and improve the safety and survivability aspects of the system, which could prevent the incalculable loss of an aviator's life.

Conclusions

There are many advantages for initiating and conducting an effective MANPRINT program. The overall effectiveness of the system (total system performance) and the safety of the soldiers are paramount reasons for establishing one. In addition, life cycle costs can be reduced by instituting MANPRINT principles during the design process.

In summary, the Apache Project Manager recognized early on the value added in applying MANPRINT design costs up front to reduce greater life cycle costs down the road. He instituted a sound MANPRINT program to make this happen. In doing so, he has spent his nickels wisely.